An Experimental Investigation of the Patterns of International Trade

Charles Noussair, Charles Plott and Raymond Riezman

California Institute of Technology and the University of Iowa

An Experimental Investigation of the Patterns of International Trade

1 Introduction

This study[1] is the first attempt to create and study a laboratory economy with some of the prominent features of an international economic system. The concept of multiple "countries" in which each country has its own technology, preferences and resource endowments, is introduced and operationalized. The questions posed in the study are related to the law of comparative advantage, factor price equalization, terms of trade, efficiency in production and exchange as guided by multiple and interacting markets and the effects of tariffs on international transactions. The study builds on previous work in the experimental study of general equilibrium phenomena.[2]

[1]The authors wish to acknowledge the financial support of the National Science Foundation and the Caltech Laboratory for Experimental Economics and Political Science. The authors also thank Charles Holt for his comments as the discussant of this paper at the meetings of the Allied Social Science Association in New Orleans, January, 1992.

[2]Goodfellow and Plott(1989) investigate the simultaneous determination of input and output prices. Lian and Plott(1990), create a macroeconomy which includes one input and one output as well as fiat money and bonds.

Because this paper carries laboratory experimental research to a new dimension of complexity and into a new field, it might be useful to address what would be the obvious concern of a skeptic. Since the world's international economies are vastly more complicated than the economies created for this study, of what relevance are laboratory generated data? The answer is that laboratory experiments are not attempts to simulate field situations, as that question of the skeptic seems to presume. Laboratory research deals with the general theories and the general principles that are supposed to apply to all economies, the economies found in the field, as well as those created in a laboratory. The laboratory economies are very simple and are special cases of the broad class of (often complex) economies to which the general theories are supposed to be of relevance. If a general theory does not work to successfully explain behavior in the simple and special cases of the laboratory then it is not general. When a model is found not working opportunity exists to modify the theory to account for the data or to reject the theory. Thus, the laboratory provides an arena in which competing notions and theories about the nature of human (and market) capacities can be joined with data. Clearly laboratory experimental work is constrained by technology and by background experimental work. When very little background work exists the experimental research strategy is to first explore what seem to be the most basic and general theoretical ideas. Then, as technology permits, successful ideas can be challenged with increasingly complex experimental environments in follow up experiments. Any laboratory experiment should be viewed as only one of the many steps needed to learn what we would like to know. This study is no different.

The focus of the study is the behavior of the entire economic system rather than the behavior of individual agents. Two behavioral models, "competitive equilibrium" and "autarky" can be applied to the experimental environments. Both models make precise predictions of the magnitude of every variable in the system, which number in the dozens. The existence of such a large number of predictions creates methodological and expositional problems. With a large number of predictions, some predictions will almost certainly be wrong. The sheer size of the undertaking makes it very easy to reject the models statistically. Therefore, after making a clear statement of the negative result that the models are rejected, the analysis of the data focuses on the general properties of interdependent markets that are suggested by the models, as opposed to a focus on the accuracy of the specific predictions of each model. In the context of the broad implications of the models, a number of results are stated.

The paper is organized in the following manner: In sections 2 and 3, the design of the experiments are described. In section 4, the theoretical models are discussed. In section 5, the data are presented and analyzed, and in section 6, the conclusions are summarized.

2 Experimental Design: Parameters

This section consists of a description of the market conditions within which the economic activity occurs. The description includes the environment, the parameters, and the form of market organization used to facilitate transactions. There are two environments: the

first is motivated by the environment of the Ricardian Model of international trade,[3] the second is a similar environment, within which the robustness of results can be investigated and in which the properties of input markets can be considered in greater detail. All markets were organized through the computerized Multiple Unit Double Auction (MUDA). For details of the operation of this form of market organization, the reader can consult Plott (1991).

Money exists in both environments. Thus, the first environment, although similar to that of the Ricardian model, differs in that the purchase of any good requires money. Money is included in the design because it is an obvious feature of any well-functioning market process, including international economies, and it is certainly useful in experimental environments in facilitating equilibration. In both environments, there is only one currency and it has value as a commodity. All experimental currency held by subjects at the end of the experiment could be converted into dollars that the subject keeps as compensation for participation in the experiment. Since the focus of this line of experimentation is international trade rather than finance, the complicating feature of multiple currencies has been omitted from the design.

Table 1 presents the experimental parameters for both of the environments that will be discussed below. Continuous approximations of the utility functions of both consumers and producers are quadratic and additively separable as shown in Table 1. The actual redemption values that were induced are contained in Table 2. Production technologies

[3]For a clear exposition of the Ricardian Model see Caves, Frenkel and Jones (1990), chapter 5. For a fascinating account of the development of the Ricardian Model see Chipman (1965).

TABLE 1: EXPERIMENTAL PARAMETERS

PREFERENCES:	ENVIRONMENT 1*		ENVIRONMENT 2			FRANC/DOLLAR CONVERSION RATE EXPERIMENT NUMBERS					
						030591	041191	04139A	032091	041091	04139B
Consumers†	$U(Y,Z) = 600Y - 40Y^2 + 700Z - 40Z^2$		$U(Y,Z) = 600Y - 100Y^2 + 600Z - 100Z^2$			040191	041191	04139A	041091	041391B	011891
Producers†	-		$U(L,K) = 600L - 100L^2 + 600K - 100K^2$								
ENDOWMENTS	L_1	L_2	L_1	L_2	K_1	K_2					
Consumers (Country 1)	2	0	5	0	3	0	1000	800	900	800	800
Consumers (Country 2)	0	2	0	3	0	5	1000	800	900	800	800
Producers (Country 1)	1	0	0	0	0	0	1000	400	400	300	300
Producers (Country 2)	0	2	0	0	0	0	1000	400	400	1000	300
PRODUCTION											
Country 1	$Y = 3L,\ Z = L$		$Y = L,\ Z = K$								
Country 2	$Y = L,\ Z = 2L$		$Y = L,\ Z = K$								
NUMBER											
Consumers (Country 1)	4		4								
Consumers (Country 2)	4		4								
Producers (Country 1)	4		4								
Producers (Country 2)	4		4								

* The experiments in Environment 1 involved either a 16 person design or 8 person design. In the 16 person design consumers and producers were all different people. In the 8 person design each consumer in country i was also a producer in country $j \neq i$. Thus, the number of agents identified by function was 16 but the number of people was 8.

† Utility functions are in franc units.

TABLE 2: REDEMPTION VALUES, ALL AGENTS, TWO ENVIRONMENTS, ONE COUNTRY (IDENTICAL COUNTRIES), ALL UNITS

Environment 1			Environment 2					
Agent Consumer	Y	Z	Consumer	Y	Z	Producer	L	K
1	600	620	1	600	450	1	600	450
	520	540		250	400		250	400
	440	480		200	50		200	50
	360	400						
	280	320	2	550	500	2	550	500
	200	240		300	350		300	350
	120	160		150	100		150	100
	40	80						
			3	500	550	3	500	550
2	560	660		350	300		350	300
	480	580		100	150		100	150
	400	500						
	320	420	4	450	600	4	450	600
	240	340		400	250		400	250
	180	260		50	200		50	200
	100	180						
	20	100						
		20						
3	560	660						
	480	580						
	400	500						
	320	420						
	240	340						
	180	260						
	100	180						
	20	100						
		20						
4	520	700						
	440	620						
	360	540						
	280	460						
	200	380						
	120	300						
	40	220						
		140						
		60						

are linear as in Table 1. In the tables, valuations are given in francs (a common name for an experimental currency). The francs are converted into dollars according to ratios known privately to agents. These conversions can differ across agents and are contained in Table 1. The variables L_i and K_i refer to the factors L and K residing in country i and Y_i and Z_i refer to the outputs Y and Z produced in country i. The endowment listed in the table is the amount each individual agent possesses at the beginning of each market period. A country's total endowment is then four times the amount listed in the table since each of the same type of agent has the same endowment.

2.1 Environment 1

Environment 1 is motivated by the Ricardian Model. In environment 1, there are two output goods (final goods) called Y and Z and an input called L. There are two types of agents: consumers and producers. Consumers are owners of the factors of production and have induced preferences for consuming the outputs Y and Z. Producers also have an initial endowment of the input and can earn profits by using the input L to produce and then sell Y and Z. All agents can also attempt to earn profits by speculating in any input or output. Neither consumers nor producers have preferences for L other than its value as an input.

Agents are divided in equal numbers into two countries. Each country includes as members equal numbers of consumers and producers. The factor of production is not mobile between countries. The final goods Y and Z can be traded in either country,

not only the one in which they were produced. The two countries differ only in their production technologies.

The economy works in the following way. Consumers sell their endowment of L to producers in their own country and then buy units of Y and Z produced in either country. Consumers get utility (U.S. dollars) from consumption and any profits made in price speculation. Producers in each country buy L from the consumers in their own country and can use L to produce Y and Z which they can sell to consumers in either country. Producers get utility (dollars) from profits earned from market and production activities.

In some experiments free international trade was permitted; in others a tariff was imposed on the imports of Z to country 1. When a tariff was in effect, it took the form of a tax of 400 francs on international transactions of the final goods. The tariff revenue was not redistributed to citizens in either country but instead was taken by the experimenter. Thus, the tariff operated similarly to a transportation cost.

2.2 Environment 2

In environment 2, the two countries have different endowments of the inputs. In addition, the inputs are endogenously and elastically supplied to producers in the sense that resources could also be consumed. Environment 2 operated as a control on environment 1 to ensure that any properties of input markets observed in environment 1 were not simply

due to the completely inelastic supply of the input. The endogenous resource property of environment 2 is a natural feature to add as a check on robustness of a model's ability to capture observed behavior because it is a general property of the field economies in which the Competitive and Autarky models are regularly applied.

In environment 2 there are two output goods called Y and Z and two inputs called L and K. There are also two types of agents: consumers and producers. As in environment 1, consumers are also owners of the factors of production. Consumers are endowed with some of both of the inputs L and K. Consumers have induced preferences for consuming the outputs Y and Z. Producers of the final goods are also consumers of the factors of production. They have no initial endowment but have preferences induced for consuming the inputs L and K and also for the money they might get by producing Y from L and Z from K and selling the output.

Participants are divided equally into two countries. Each country has an equal number of consumers and producers. Both types of agents can trade the inputs L and K only with agents in their own country. The final goods Y and Z can be traded internationally. No tariffs existed in any of the experiments in which environment 2 was implemented.

Consumers sell their endowment of inputs to producers in their own country and consumers buy units of Y and Z produced in either country. Producers can buy L and K from consumers in their own country. Producers can consume any part of the purchases of L and K and can use the remainder to produce Y and Z, which they can then sell in either country.

3 Experimental Design: Procedures

A total of ten experiments were conducted. Table 3 provides a summary of treatments. Experiments are indexed by the date of the experiment. Two subject pools were used. The experiments involved both 8 people and 16 people. The smaller numbers were dictated by cost and difficulties in recruiting subjects.

In the conditions of environments 1 and 2, there were six and eight market[4] respectively operating simultaneously. Each variable had its own market, e.g., output Y_i, Y produced in country i, had its own market. The production process allowed subjects to transfer units from and to inventories of certain markets in fixed ratios. Production was accomplished through a series of key strokes. To consume units, subjects held them in their inventory at the end of a market period.

Subjects, undergraduates at the California Institute of Technology and at the University of Iowa, had at least one half hour of prior training in use of MUDA. [5] The MUDA software is accompanied by a tutorial that explains the key functions to subjects and lets subjects practice using the keys in an environment containing randomly behaving robots. Appendix A contains instructions read to subjects. During period 0 and period 1 accounting records were checked carefully for mistakes and spot checks were conducted

[4]The names L and K were not used to label the markets in any experiments because they might suggest behavior to the subjects if subject thought that L and K represented labor and capital. The labels used in markets are explained in Appendix A.

[5]Although Caltech subjects were only allowed to participate in one experiment in this particular line of experimentation, some of the Caltech subjects had been in other market experiments. None of the U. of Iowa subjects had been in other market experiments previously, although experiments 041391A and 041391B used only subjects who had been in one of the previous experiments in the series.

TABLE 3: SUMMARY OF EXPERIMENTS

Exp.No.(date)	Tariffs y/n	Periods	Environment	Subj. Pool	No. Subjects
030591	N	11	1	Caltech	8
040191	N	10	1	Caltech	8
041191	N	9	1	U.Iowa	16
041391A	N	10	1	U.Iowa (exper.)*	16
032091	Y	10	1	Caltech	8
041091	Y	9	1	U.Iowa	16
041391B	Y	10	1	U.Iowa (exper.)*	8
0112890	N	9	2	Caltech	16
113090	N	11	2	Caltech	16
011891	N	10	2	Caltech	16

*Subjects had experience in one of the earlier experiments listed here.

in later periods.

The experiment was divided into trading periods, at the beginning of each of which, subjects received new endowments and redemption values which were the same each period. At the beginning of the experiment there was a long practice period (period 0) for 15 mins. in which no money was paid. Market periods averaged 10 minutes in length.

4 Models

Some of the models described below rely on strong assumptions. The complex environments of the experimental markets are much richer than those that the models describe. However, experimental economics has demonstrated that models frequently have surprising power even when applied to environments much more complex than the structure of the models. The questions that will ultimately be posed concern the identification of models that can provide intuition needed for help with the interpretation of market data.

4.1 The Competitive Model

This section contains a brief elaboration and review of the competitive model. The computation and description of the competitive equilibria for both environments are in Appendix C. Recall that the first environment has two outputs, both of which can be produced with the same input, paralleling that of the Ricardian Model of international

trade. In the Ricardian environment there are two final goods, Y and Z, each of which are produced by one factor, L. There are two countries which may differ in their endowments of the factor. The factor cannot cross national boundaries, and is supplied inelastically to the markets. The two countries are assumed to have different production functions so that each country has a comparative advantage in production of one of the goods. Without loss of generality, call the country with a comparative advantage in the production of Y country 1. The two countries have identical aggregate demand for both goods. In autarky, the price ratio $\frac{P_Z}{P_Y}$ should be greater in country 1 than in country 2. That is, country 1 can produce good Y more cheaply in terms of good Z then can country 2. If trade between the two countries is permitted, then comparative advantage dictates than country 1 specializes in and exports good Y. Similarly, country 2 specializes in and exports good Z. If the final goods are traded without restrictions, the prices of the final goods, Y and Z, will be the same across countries and the price of L generally will be different in each country.

Thus, for environment 1, the competitive model predicts that countries 1 and 2 would produce exclusively goods Y and Z respectively and that each of the two countries would be a net exporter of the output which it produces. In particular country 1 would produce only Y and country 2 would produce only Z. The prices of the outputs would be equal in each country according to the model and the prices of inputs would equal their marginal revenue products.

If a tariff were imposed on the country 1 imports of Z in environment 1, then according to the competitive model international trade of Z would decline. The price of Z in country

1 would increase and the price of Z in country 2 would fall. The input price in country 2 would also decline since its marginal revenue product would be lower. The tariff imposed was 400 francs.

In environment 2, the competitive model predicts that each country would produce both output goods. Country 1, however, would be a net exporter of Y and country two would be a net exporter of Z. Under conditions of free trade, the prices of outputs would be equal across countries. Since derived demand would be identical in both countries, then the factor prices would also be the same and would equal the factors' marginal revenue product. The price of each of the four types of goods in country 1 would equal its price in country 2. The prediction of the equality of input prices across countries in environment 2 will be referenced to as the factor price equalization principle. Notice that for the parameter values imposed in this environment, factor price equalization is predicted even though the factors cannot be traded internationally.

4.2 Autarky

A natural alternative model to use is the autarky model. It is useful because it characterizes one benchmark of the potential behavior which a system might exhibit. Its predictions are based upon the proposition that no trade will occur across national boundaries. This model predicts the prices and production levels in each country which would occur in a competitive equilibrium with no international transactions permitted. This model thus offers specific predictions of prices, patterns of production, international trade, and

the effects of tariffs.

For environment 1, the autarkic model predicts that specialization would not occur in either country, and that there would be no international trade or payment imbalances. Since there is no trade across national boundaries, the predictions of this model are unaffected by the imposition of tariffs. According to the autarky model, prices of all goods would be different in the two countries.

The autarkic model also makes predictions concerning production and trade in the two countries in environment 2. Both countries produce both goods but in different quantities than in the competitive equilibrium. Autarky predicts that there will be no international trade and that both input and output prices will be different across countries. The wage price ratio predictions are identical to those predicted by the competitive model. There should be no payment imbalances. The predictions of the autarky model are computed in a similar way to the competitive model. The computations are available from the authors.

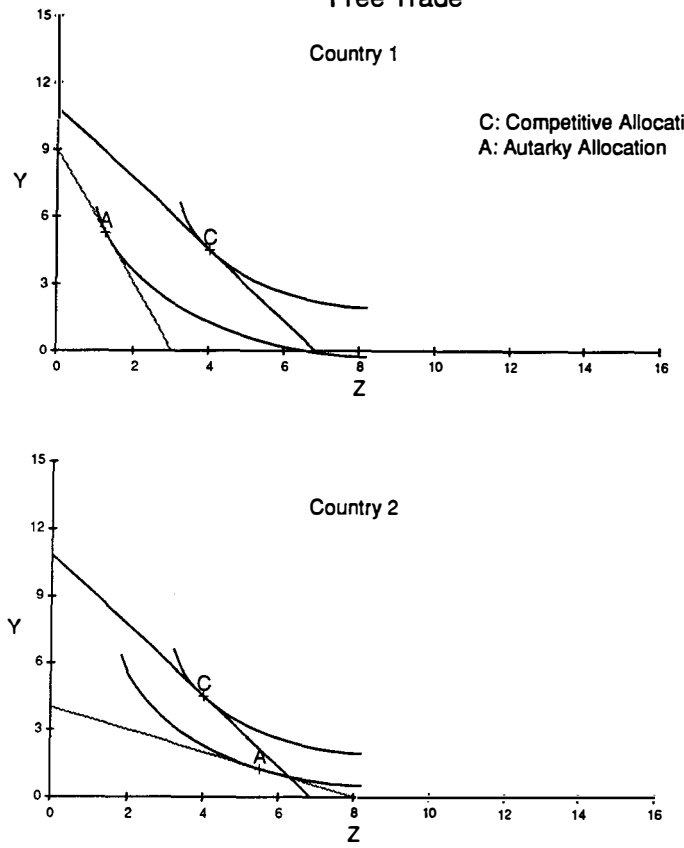
The specific predictions of the two models in the two environments are given in table 4. An illustration of the autarky and of the competitive models is given in Figure 1 from an individual's point of view. In the figure, if trade between countries does not occur, an individual in country 1 achieves his highest indifference curve given initial endowments, by consuming 5.25 units of Y and 1.25 units of Z. Similarly, an individual in country 2 reaches his highest possible utility level by consuming 1.25 units of Y and 5.5 units of Z. In the experimental environment, money, which has value to all agents,

TABLE 4: SPECIFIC PREDICTIONS OF THE TWO MODELS: PRODUCTION AND EXPORT QUANTITIES AND PRICES IN FRANCS WITHOUT TARIFFS AND (WITH TARIFFS)

	ENVIRONMENT 1				ENVIRONMENT 2	
	Competitive		Autarky		Competitive	Autarky
PRODUCTION						
Y_1	36	(36)	21	(21)	12	10
Y_2	0	(0)	5	(5)	4	6
Z_1	0	(0)	5	(5)	4	6
Z_2	32	(32)	22	(22)	12	10
EXPORTS						
Y_1	18	(18)	0	(0)	4	0
Y_2	0	(0)	0	(0)	0	0
Net Y (from 1 to 2)	18	(18)	0	(0)	4	0
Z_1	0	(0)	0	(0)	0	0
Z_2	16	(6)	0	(0)	4	0
Net Z (from 2 to 1)	16	(6)	0	(0)	4	0
PRICES						
L_1	720	(720)	600	(600)	200-250	150
L_2	760	(360)	520	(520)	200-250	300-350
K_1	-	-	-	-	200-250	300-350
K_2	-	-	-	-	200-250	150
Y_1	240	(240)	200	(200)	200-225	150
Y_2	-	-	520	(520)	200-225	300-350
Z_1	-	-	600	(600)	200-225	300-350
Z_2	380	(180)	260	(260)	200-225	150

Fig. 1

Continuous Approximation of Representative Consumer's Indifference Curve and Relative Prices Under Autarky and Free Trade



may be borrowed costlessly in large quantities from the experimenter. For this reason, there is no budget constraint. The optimal consumption bundle is determined by the prices of Y and Z and by the consumer's utility for Y, Z and money. The autarky consumption bundles of individual consumers in the two countries are labelled with A's in the figure. If free trade occurs, then each country can achieve a higher utility level by specializing in the commodity in which it has a comparative advantage and then trade internationally at the world competitive equilibrium price. The competitive equilibrium individual consumption bundles are labelled with C's. In the competitive equilibrium, each country consumes 18 units of Y and 16 units of Z.

5 Results

In making the statistical inferences below, we implicitly assume that each market period is an independent observation. Although the periods are not independent, the statistics are useful in describing some of the phenomena we observe in the data[6]

[6]We use both the Sign test and the Wilcoxon rank sum test. The sign test is a procedure for testing hypotheses about the median of a continuous distribution. If X denotes the random variable whose distribution is under investigation, then $P(X \leq \mu) = P(X \geq \mu) = .5$. The general null hypothesis has the form $H_0 : \mu = \mu_0$.

When $\mu = 0$, any X_i is equally likely to be positive or negative. If, however, the true value of μ is much greater than 0, we would expect most of the observed X_i's to be positive. Define the test statistic Y = the number of X_i's such that $X_i > 0$. For testing H_0, versus $H_a : \mu > 0$, the sign test rejects H_0 when the test-statistic $Y \geq c$. If we regard each X_i as a trial, and the data consist of a set of n identical trials, and if we define a positive X_i to be a success and a non-positive X_i as a failure, then we have p = P(success) = $P(X_i > 0) = P(X_i > \mu) = .5$. Then, when H_0 is true, the statistic Y has a binomial distribution with parameters n and p (p = .5). Therefore, if the null hypothesis is $H_0 : \mu = 0$ and the alternative hypothesis is $H_a : \mu \neq 0$, then we reject H_0 if either $Y \geq c$ or $Y \leq (n - c)$. When p = .5 and $n \geq 10$ the binomial distribution can be approximated by a normal distribution. For most of our statistical tests, X_i equals the observed value of a variable for a market period minus a theoretically predicted value of the variable. If we reject the hypothesis that $\mu = 0$, than we reject the hypothesis that the median of the observed values of the variable equals the theoretical prediction.

The Wilcoxon Rank-Sum test is a procedure which has the desired level of significance for a very large class of underlying distributions. Under the assumption that two independent random samples, are drawn from continuous distributions with the same shape and spread, the Rank Sum statistic tests whether the means of the two distributions are equal. We use the rank sum test when we consider whether the mean value of a variable is different in the early vs. late periods of an experiment, or different in the tariff vs. no tariff conditions. See Devore (1982) or another introductory statistics text for a description and derivation of the sign and the rank sum tests.

The principal observations are summarized in Result 0 thru Result 8. A typical set of price time series from environment 1 is represented in Figures 2 and 3. The input prices for each country separately are in the Figure 2 graphs. The output prices are pooled across countries for each of the two outputs and are given in the two graphs of Figure 3. The horizontal lines are the competitive equilibrium prices.

Notice from the figure, that the transaction prices seem to be moving toward the competitive equilibrium prices over time. While this tendency of convergence will ultimately be shown to be true, the first pass at the data holds to strict standards. As can be seen the prices are not at the competitive equilibrium. As we indicated earlier, in an economic system as complicated as these, it is very easy to statistically reject the benchmark models. This indeed proved true.

Result 0: Both the competitive and the autarky models can be statistically rejected.

Support: The world production predictions of the autarky model are rejected for both goods in the conditions of environment 1. That is, the hypothesis that the median world production is less than or equal to the autarky level is rejected at the ($p < .05$) level for both output goods in both tariff and no tariff conditions. Similarly, the competitive

Figure 2: Input Price Time Series, Experiment 041391A, Country 1 (Upper Graph) and Country 2 (Lower Graph)

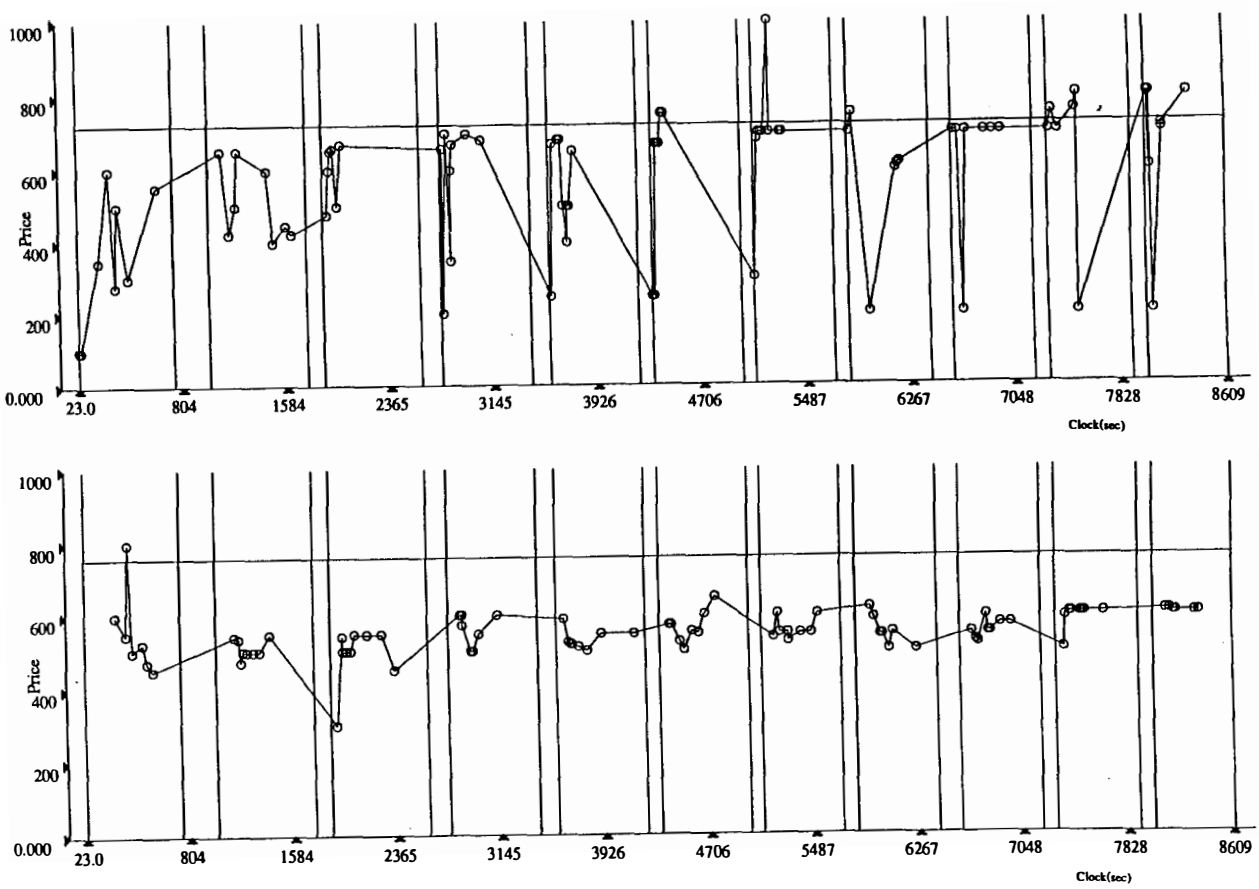
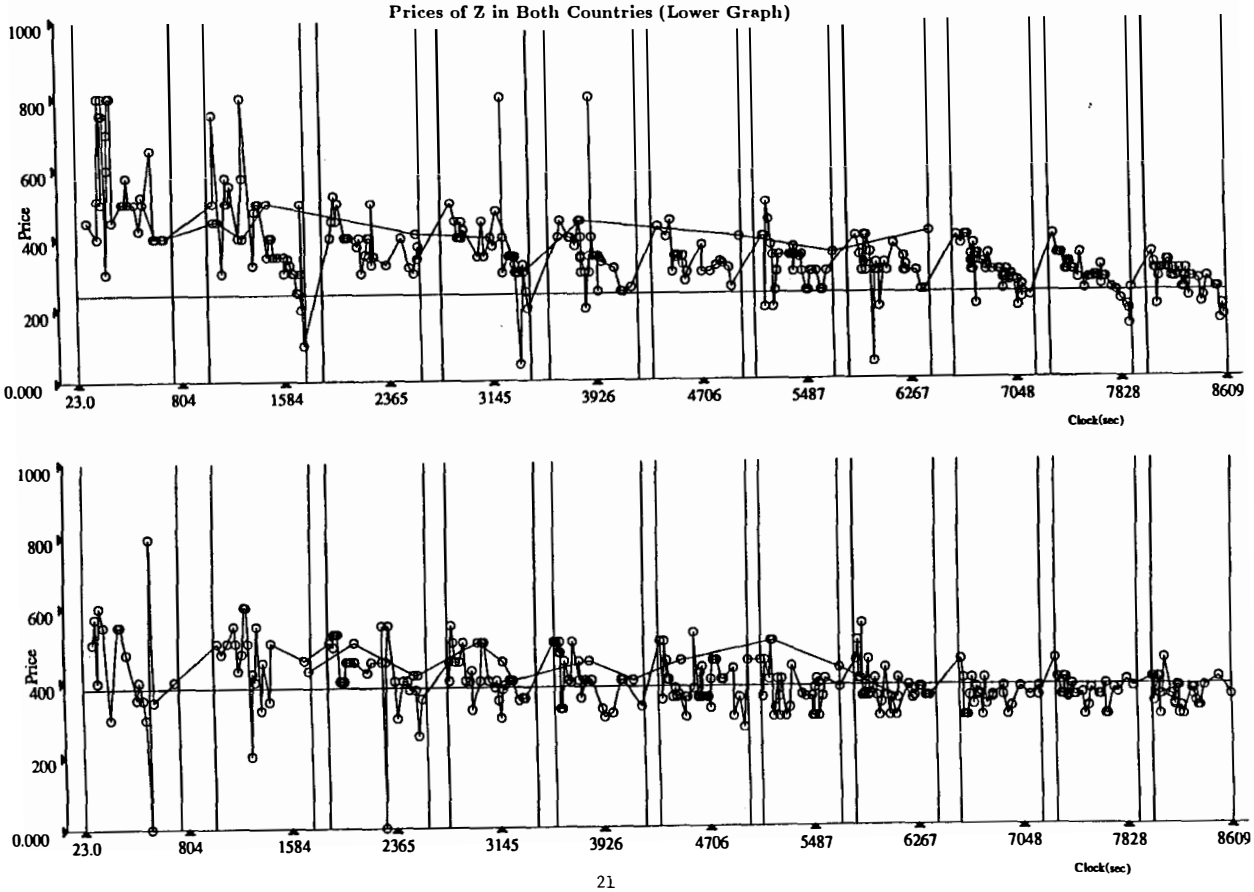


Figure 3: Output Price Time Series, Experiment 041391A, Prices of Y In Both Countries (Upper Graph) and Prices of Z in Both Countries (Lower Graph)



model can be rejected. That is, the hypothesis that world production is greater than or equal to the predictions of the competitive model is rejected for Y in both conditions and for Z under tariff conditions (but not in the no tariff condition) at ($p < .05$). In all three treatments, and in almost all markets, we reject hypotheses that the median observed export levels equal the predictions of both of the models at the ($p < .05$) level. For environment 1, we reject the predicted prices of both models for almost all markets, (there are two exceptions out of 16 markets) at the ($p < .10$) level. For environment 2, we reject both models as predictors of prices in all output markets and the autarky model as a predictor of prices in all input markets at the ($p < .05$) level. For the exact levels at which predictions of the models are rejected please refer to Appendix B, Tables B1 and B2. For averages of prices in all markets, net exports and production see Tables B3 thru B20. □

It is not surprising that the models are statistically rejected. However, more importantly, one of the models (the competitive model) does describe the qualitative features of the data quite well as the following series of results will show. Result 1 summarizes observations concerning whether or not the law of comparative advantage can be seen in operation. The notion is that countries produce more of and export the output in whose production they have a comparative advantage. Recall that the law of comparative advantage holds that country 1 should specialize in and be a net exporter of good Y. Country 2 should specialize in and be a net exporter of Z.

Result 1: The law of comparative advantage accurately predicts trade patterns.

Support: In every period of every experimental session, in environment 1 and in 87% of all periods in environment 2, net exports of both outputs are in the direction predicted by the competitive model. Average net exports by country 1 of Y are 11.5 units per period in environment 1 without tariffs, 8.3 with tariffs and 2.2 in environment 2. Average net exports of Z by country 2 are 10.3 in environment 1 without tariffs, 2.8 under tariffs and 2.7 in environment 2. The sign test leads us to reject the null hypothesis that either the net exports of Y from country 1 to country 2 are less than zero or that net exports of Z from country 2 to country 1 are less than zero. (The z-scores for the three treatments are respectively 6.32, 5.47 and 4.74 and the p-values are less than .001 in all treatments.) Country 1 is clearly exporting more Y than it imports. Country 2 is exporting more Z than it imports. □

Of course, the law of comparative advantage can be viewed as an independent principle or it can be viewed as a consequence following from the assumptions of the general competitive model. Thus, since the result lends support to the competitive model, it is natural to inquire about other features of the model. The competitive model not only predicts the direction of net exports, as captured by the law of comparative advantage as discussed in Result 1, it also predicts patterns of production. For environment 1 the competitive model predicts that no units of Y would be produced in country 1 and that no units of Z would be produced in country 2. Result 2 reflects considerations of those precise implications of the competitive model under both tariff and no tariff conditions.

The support for Result 2 can be seen in Figures 4 and 5 for environment 1. The figures contain world aggregate production for early periods and for later periods. The world production frontier is shown in the figure. The competitive model predicts that world production will be at the "kink" in the frontier. Figure 4 contains data from environment 1 experiments in which there were no tariffs. Figure 5 contains the data from environment 1 experiments in which tariffs existed. As can be seen in both figures, aggregate production is nearer the competitive equilibrium in the later periods.

Result 2: Aggregate production patterns are converging toward those predicted by the competitive model.

Support: The degree of support for the proposition varies with the experimental conditions. Support is strongest for environment 1. Under free trade (no tariffs) production is ceasing where it should cease. Average production of Y by country 2 was 3.3 in periods 1 thru 4 and 0.8 in periods 5 thru 11, (the competitive equilibrium is 0 units.) Average production of Z in country 1 was 3.1 units in the first four periods and 1.3 in the later periods (competitive equilibrium is 0.) A rank sum test comparing the production of Y in country 2 in the early vs late periods can be used to reject the hypothesis that the production quantity is increasing (z-score = 1.81, p-value < .05 and similarly the production of Z in country 1 does not increase with time (z-score = 1.29, p-value < .1). Production is also taking place in the locations and approaching the quantities predicted by the competitive model. Production of Y in country 1 and Z in country 2 is at the respective average level of 31.5 and 30.4 in late periods. The competitive equilibrium levels are 36 and 32 respectively.

Fig. 4

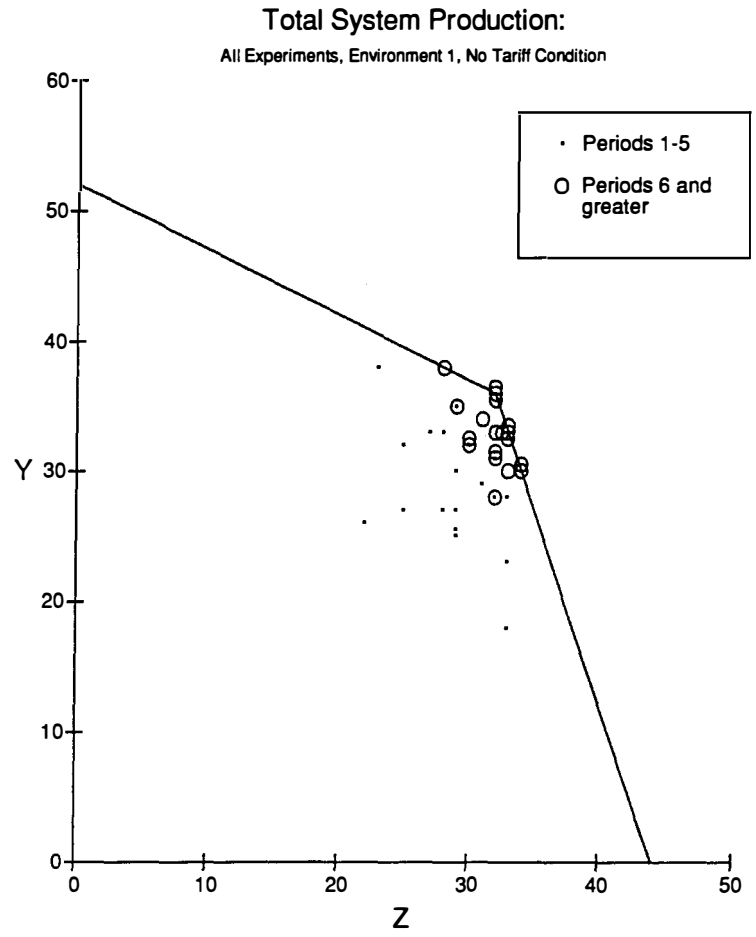
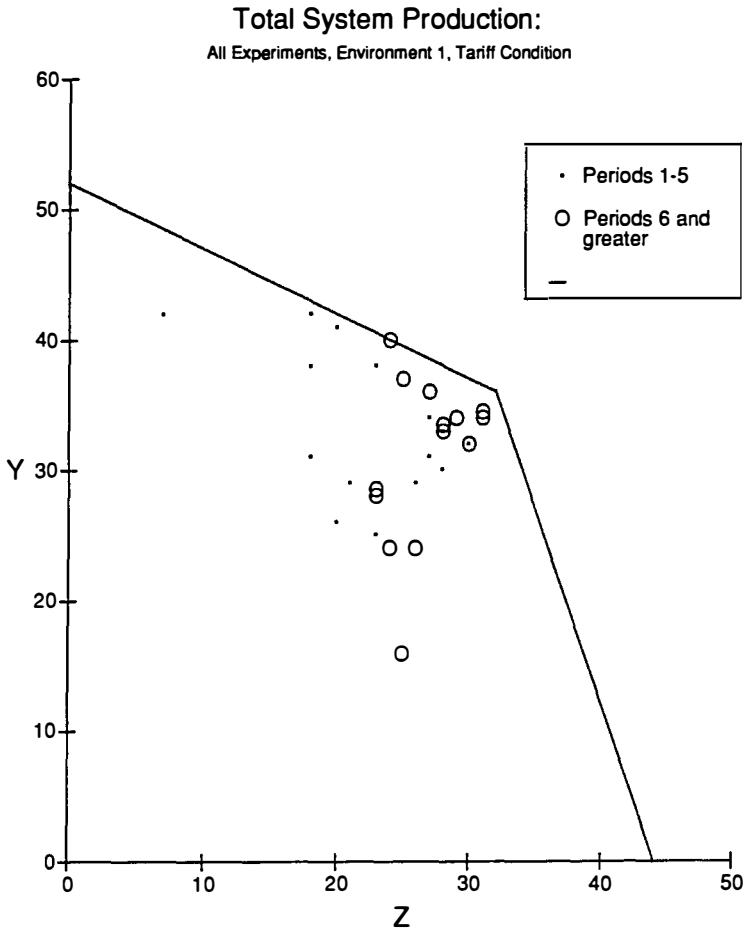


Fig. 5



In environment 1 under tariffs production is ceasing where it should but not so rapidly. Average production of Y in country 2 is 5.8 units in the early periods and 4.0 in the later (the hypothesis that the quantity is increasing is rejected, z-value = 2.99, p-value < .01.) Production of Z in country 1 is 2.7 in both the early and late periods so the hypothesis of convergence to the zero levels predicted cannot be supported. Similarly, production takes place where it should take place and country 2 production of Z is increasing. However, country 1 production of Y is not increasing.

In environment 2 the support for the result is the weakest. Production of Y is going up in country 1 (from an average of 8.9 in early periods to 10.9 later, as compared to the 12 predicted by the competitive model) and it is going down in country 2 (from 6 to 4.2 as compared to the competitive equilibrium of 4.) However, relative production of Z is as quantitatively predicted but the magnitudes are off and the data shows no movement. □

Result 2 is focused on production. The next result, Result 3, considers consumption patterns. Do individual consumption levels converge with replication of periods to the predictions of the competitive model?

Result 3: Individual consumption patterns are converging to those predicted by the competitive model

Support: The deviation in individual consumption from the quantities predicted in the competitive are diminishing over time (see Table 5). In the table the data are pooled for all of the experimental sessions. From the table, it is evident that the absolute value of the deviations are smaller in the later periods than in the earlier periods. For example,

TABLE 5: DEVIATIONS OF INDIVIDUALS' HOLDING FROM COMPETITIVE EQUILIBRIUM PREDICTIONS (BY PERIOD)

PERIOD

			1	2	3	4	5	6	7	8	9
OUTPUT	**Y**	μ	-0.91	-0.46	-0.58	-0.45	-0.46	-0.40	-0.24	-0.18	-0.28
		σ	1.63	1.49	1.29	1.38	1.09	1.11	0.91	0.98	1.05
	Z	μ	-0.95	-0.79	-0.60	-0.40	-0.30	-0.31	-0.21	-0.23	-0.39
		σ	1.84	1.64	1.15	1.55	1.25	1.26	1.06	1.07	1.16

$$\mu = \sum_i (x_i - x_i^*)/N$$

$$\sigma = [\sum_i (x_i - x_i^*)^2/N]^{\frac{1}{2}}$$

Where x_i = actual holdings of agent i
x_i^* = competitive equilibrium holdings of agent i
N = total number of observations (consumers times experiments)

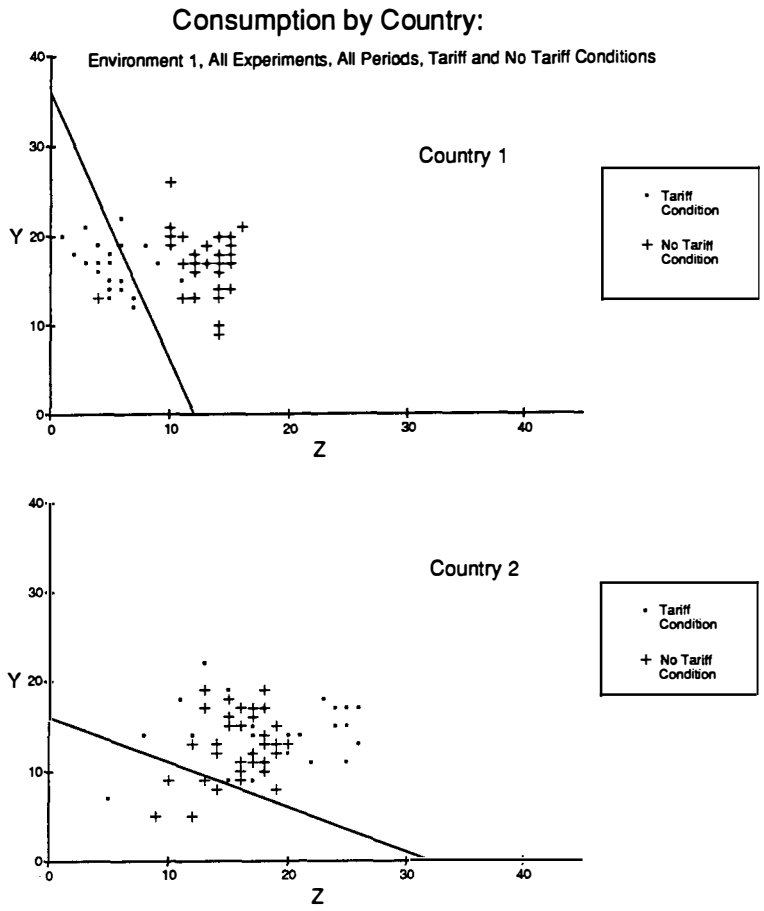
the mean deviations from the competitive equilibrium fall consistently over the first four periods for both Y and Z. Similarly the standard deviations during the first periods are higher than those in the last periods. The hypothesis that the absolute value of the deviations for periods 1 thru 3 are smaller than or equal to those for periods 7 thru 11 can be rejected at $p < .01$. □

The addition of tariffs on imports of country 1 changes the predictions of the competitive model. According to the model, the tariff discourages the export of Z by country 2 and encourages the home consumption of Z by country 2. Figure 6 demonstrates the differences in consumption patterns in environment 1 that were caused by the tariff. The figure shows aggregate consumption for each country with the top panel containing data from country 1 and the bottom, data from country 2. The production possibilities curve is shown for each country as a point of reference. Note that the consumption of Z is shifted from country 1 to country 2 with the imposition of the tariff.

The change in consumption that is apparent in the figure reflects a deep interaction between principles of economics and the parameters of these economies. The tariff, 400 francs per unit of Z imported by country 1, is not so high as to prevent specialization in both countries in the same levels of output as they would specialize under free trade according to the competitive model. That is, the world patterns of production should not be altered by the tariff in this version of the Ricardian model. However, the competitive model predicts that the reduction in exports of Z would lead to lower system efficiency[7].

[7]System efficiency is measured as actual social income (in francs) divided by social income at the competitive equilibrium. See Plott and Smith (1978) for a discussion of the concept in a single market economy. In a multiple market economy the measure can be influenced by scale choices.

Fig. 6



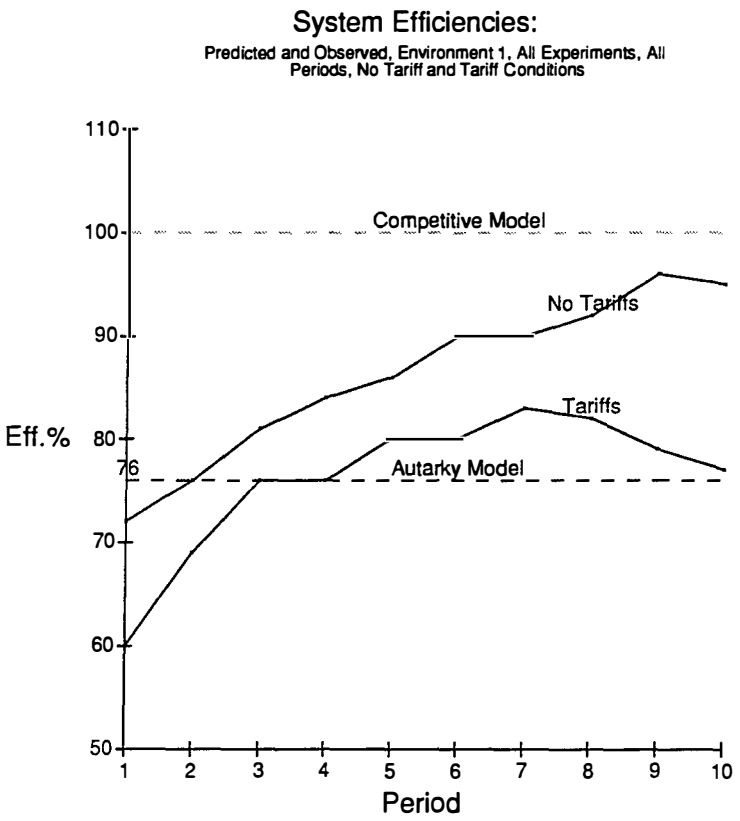
The impact of the tariff is to block some gains from international exchange. System efficiency thus falls due to the imposition of a tariff. This property is captured by the next result. Generally, we find that the tariff affects trade volume, efficiency and prices in the way that the competitive model predicts.

Result 4: Tariffs reduce international trade and market efficiency, as predicted by the competitive model. Prices also differ in the manner predicted by the competitive model.

Support: The relevant data is for environment 1. Average net exports per period are 10.3 without the tariffs and 2.8 under tariffs. We reject the hypothesis at the $p < .01$ level that exports of Z are lower or equal under free trade than under tariffs. Refer again to Figure 6 which depicts consumption in the two countries in all experiments in the condition of environment 1 with and without tariffs. Market efficiency under tariffs is compared to that without tariffs for the pooled environment 1 data in Figure 7. As can be seen for each period average efficiency under the no tariff condition is higher than average efficiency of the tariff condition.We reject the hypothesis that efficiency is equal in the two conditions or higher under tariffs ($p < .05$). We also reject the hypothesis, using the rank sum test, that the prices of L_2 or the prices of Z_2 are equal under the tariff and in the absence of the tariff. The average prices of L_2 and Z_2 are 550 and 467, respectively under no tariff conditions and are respectively 402 and 380 under tariffs. As the competitive model predicts, they are both lower in the tariff case. □

The comparative statics of the tariff summarized by Result 4 are interesting because

Fig. 7



they compare disequilibrium states with and without the tariff and not the equilibrium states as assumed by theory. The next results move on to consider the nature and degree of this disequilibrium behavior with a focus on prices. Average price data are contained in Table 6. As is stated in the results, the output prices are moving toward the competitive equilibrium.

Result 5: Output prices are converging toward the competitive equilibrium price from above.

Support: The time trend of average prices toward the competitive equilibria (in parenthesis) establishes the result. In periods 1 thru 4, average (competitive) prices of Y_1 and Z_2 were 419 (240) and 508 (380) in environment 1 with no tariffs and in periods 5 and greater they were 312 and 439 respectively. In environment 1 with tariffs during periods 1 thru 4 the Y_1 and Z_2 prices were respectively, 418 (240) and 462 (180) and were 348 and 348 in the later periods. In environment 2, in which all competitive equilibrium prices are the same at (200-225), the average prices in periods 1 thru 4 for Y_1, Y_2, Z_1, Z_2 were respectively 391, 381, 368 and 345; and for periods five and greater the averages were 274, 287, 273, and 288. Using the rank sum test, we reject the hypothesis that average per period prices are further from the competitive equilibria in the later periods at the 5 percent level for all output markets. □

While output prices move in an understandable way, as summarized by Result 5, input prices are more complex because of the nature of derived demand. The next result suggests that the deviation of factor prices from the competitive equilibrium is not only

TABLE 6: AVERAGE PRICES OF INPUTS AND OUTPUTS EARLY PERIODS AND LATE PERIODS

Environment 1 (No Tariffs)

Periods	L_1	L_2	Y_1	Y_2	Z_1	Z_2
1-4	603	503	419	476	535	508
5 and greater	678	600	312	456	530	439
Competive Equilibrium	720	760	240	—	—	380
Autarky	600	520	200	520	600	260

Environment 1 (Tariffs)

Periods	L_1	L_2	Y_1	Y_2	Z_1	Z_2
1-4	543	287	418	417	472	462
5 and greater	662	477	348	328	591	348
Competive Equilibrium	720	360	240	—	—	180
Autarky	600	520	200	520	600	260

Environment 2

Periods	L_1	L_2	K_1	K_2	Y_1	Y_2	Z_1	Z_2
1-4	288	295	273	257	391	381	368	348
5 and greater	240	256	228	238	274	287	273	288
Competive Equilibrium	[220-250]	[200-250]	[200-250]	[200-250]	[200-225]	[200-225]	[200-225]	[200-225]
Autarky	150	[300-350]	[300-350]	150	150	[300-350]	[300-350]	150

due to a lack of equilibrium in the output price market but that factors have their own independent dynamic structure of adjustment. However, the direction of adjustment in the factor markets is toward the equilibria of the competitive model.

Result 6: Factor prices are below marginal revenue products. That is, the input/output price ratio is below the marginal product. The convergence is in the direction of the competitive equilibrium relationships.

Support: The conditions for profit maximization under competitive conditions is simply that factor price = marginal physical product times output price. Since production technologies are linear, the marginal physical product is a constant. It follows that the ratio of factor price to output price when compared to marginal products can then be used to determine whether the input demand conditions are satisfied.

Table 7 contains the average factor price to average output price ratios for factor/output pairs for which the factor is used in the production of the output. In all cases the factor price to output price ratio is below the marginal physical product (shown at bottom of table.) It follows that factor prices are below marginal revenue products in all cases. We can also reject the hypothesis that the factor price to output price ratio is higher in the early periods in all markets at the 5 percent level. □

Two possible reasonable explanations of the observed input/output price behaviors summarized in Result 6 are consistent with behaviors found in other experimental markets. The first is that the asymmetry of rents received by sellers and buyers of the factors (sellers receive more rents) leads to lower transaction prices because rents are split (see

TABLE 7: RATIO OF AVERAGE INPUT PRICES TO AVERAGE OUTPUT PRICES FOR EARLY AND LATE PERIODS AND THE COMPETITIVE EQUILIBRIUM RATIO

Periods	Environment 1 No Tariffs		Environment 1 With Tariffs		Environment 2			
	$\frac{L_1\text{price}}{Y_1\text{price}}$	$\frac{L_2\text{price}}{Z_2\text{price}}$	$\frac{L_1\text{price}}{Y_1\text{price}}$	$\frac{L_2\text{price}}{Z_2\text{price}}$	$\frac{L_1\text{price}}{Y_1\text{price}}$	$\frac{L_2\text{price}}{Y_2\text{price}}$	$\frac{K_1\text{price}}{Z_1\text{price}}$	$\frac{K_2\text{price}}{Z_2\text{price}}$
1 thru 4	1.44	0.99	1.30	0.82	0.73	0.78	0.73	0.75
5 and greater	2.17	1.37	1.90	1.37	0.88	0.89	0.84	0.83
Competitive Equilibrium (Marginal Product)	3	2	3	2	1	1	1	1

Smith and Williams (1982). However, if this is the explanation then the factor prices should approach equilibrium from below. In all environments, as long as output prices are at or above the competitive equilibria prices, producer surplus is greater than consumer surplus in the appropriate partial equilibrium model. As is evident in Table 6, factor prices in environment 2 do not approach the competitive equilibria from below.

Since factor prices do not approach equilibria from below in environment 2 this first (rent splitting) explanation must be rejected. The other possible explanation is that the buyers of the factors face a market risk. The buyer may not able to sell the final goods produced with the factor. In the experiments producers must buy the input, then produce and sell the output. This takes time and the possibility that prices could change or the possibility that time could run out, create real risks for producers. As a compensation to the producer for bearing this risk, a "return for risk bearing," the factor/output price ratio starts low and adjusts upwards. Risk of this type might be a general property of interdependent markets and if it is then the input/output price adjustments observed in the experiments might also be observed in the field. Regardless of the interesting separate dynamics, the most fundamental theoretical property derived from the competitive equilibrium model still holds as is captured by Result 7.

Result 7: Factor prices adjust across countries (in environment 2) as predicted by the factor price equalization principle.

Support: In environment 2 competitive equilibrium output prices are all the same (200 - 250) and competitive equilibrium input prices are all the same (200 - 225.) We

cannot reject the hypothesis that the prices of any of the four types of goods are the same in the two countries. The z scores are .73, .36, 1.09, and .36 for L, K, Y and Z respectively. None of these are significant at the 10 percent level. Per period average prices for the four inputs, L_1, L_2, K_1, K_2 are respectively, 261, 272, 248 and 244. Outputs Y_1, Y_2, Z_1 and Z_2 have average prices respectively, of 323, 324, 310, 312. □

The equality of factor prices for our parameters in environment 2 is a theoretically sound result. Since the outputs trade internationally they must trade at the same price in the two countries. Therefore, because production technology is linear and identical in the two countries, the marginal revenue product of the inputs and therefore their wages should be the same even though the inputs themselves do not trade internationally. Interestingly, in our experiment, we observe equality of input prices across countries even though these input prices are not equal to the marginal revenue product of the inputs.

Since profits can be viewed as a return to a special input (risk bearing,) the pattern of profits is worthy of special investigation. In the competitive model, equilibrium profits from production are zero. The next result demonstrates that the patterns of profits follow the laws suggested by the competitive model.

Result 8: Profits from production are positive but fall over time.

Support: For environment 1 we reject at the 5 percent level the hypothesis that total profits from production are greater in periods 5 than in periods 1 thru 4 or are equal in the early and late periods. An ambiguity in the concept of "profit" exists

for environment 2 and for all 8 person experiments. Under those conditions producers could also consume, so profit calculations can be performed only under some clearly stated convention. In order to conserve space we observe that the ratio of input prices to output prices falls over time. Under any reasonable definition of profits it must be the case that profits fall over time as well. □

Finally, we make three observations. The first is a summary about the autarky model which is included for completeness. Observations 2 and 3 are different. Neither observation has particular foundation in theory. However, following the statement of the observations we provide a conjecture about the nature of the dynamics at work in these markets. If the conjecture is correct then the third observation can be explained.

Observation 1: The competitive model explains the data better than the autarky model.

Support: The support is contained in previously stated results. In Result 1 and Result 2 the production data from environment 1 reveals that the systems of production and export for all goods are moving toward the competitive equilibrium and away from autarky. The production data from environment 2 seems to clearly favor neither model. From Result 4, we see that tariffs had effects predicted by the competitive model while autarky predicted that tariffs would have no effects. Output prices are converging to the competitive equilibrium as opposed to the autarky levels (Result 5.) The only real exception is Z, under the tariff condition but here the volume was very low. The only input prices that move toward autarky and away from the competitive equilibrium are

those for L_2 under the tariff condition. □

Observation 2: In the no tariff condition, a large amount of exporting going back and forth between the two countries was observed. The trading appeared to be international speculation and seemed to help markets converge.

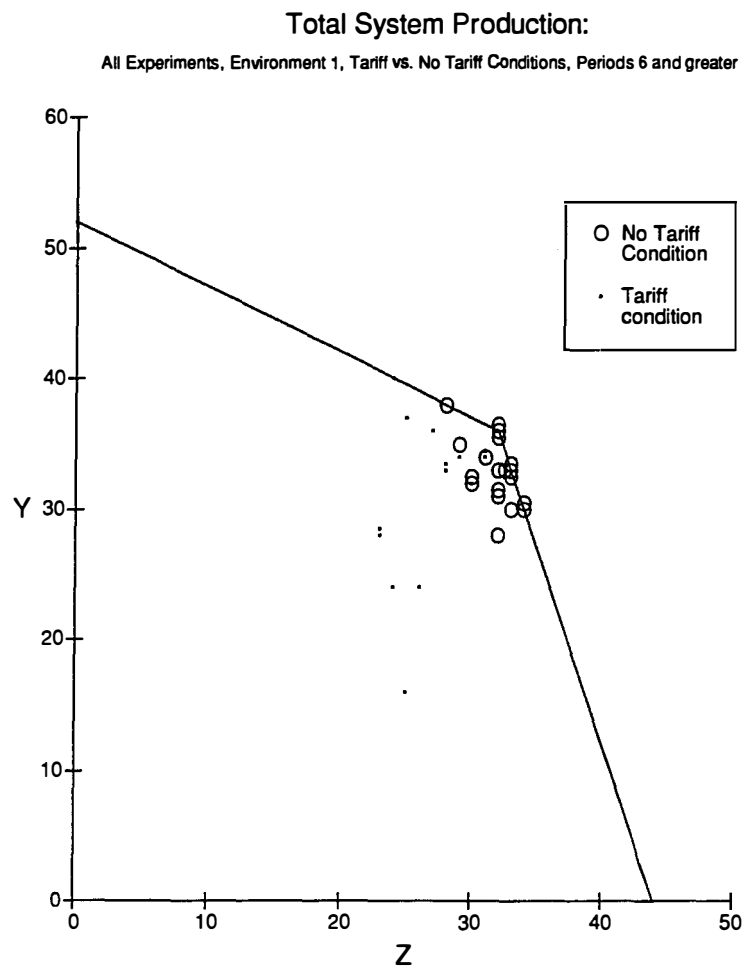
Support: Net exports constitute only 6.3.8 percent of total international trade under free trade in environment 1. The rest of the volume comprised units which had been or were being returned to their country of origin. When tariffs were imposed the cross trading in Z was essentially eliminated. □

Observations 3: Contrary to the prediction of the competitive model, the tariff reduced production efficiency.

Support: Figure 8 contains world production data for the last few periods of experiments with tariffs and experiments without tariffs. These are periods after which some equilibration has taken place. Recall that in this version of the Ricardian model the tariff should have no influence on production. As is clear from the figure, production was less when the tariff existed. □

A review of some of the results presented above provides surprisingly strong support for a conjecture about the nature of the dynamics at work in these markets. Collecting Results 5, 6, 7 and 8 along with Observation 3 reveals a pattern of the disequilibrium dynamics. The system appears to be moving toward the competitive equilibria along a qualitatively distinctive path. The term "conjecture" is used because the path cannot be

Fig. 8



deduced from accepted theory even though it is supported by much theoretical intuition.

An explanation of the dynamics, which we shall call the "risk compensated input/output price adjustment process," begins with the observation that markets have an inherent randomness as part of the general equilibration process. This randomness creates a risk for producers who must commit to the purchase of resources and who face the possibility of losses if the product produced from the resources cannot be sold at sufficiently high prices. Accordingly, producers restrict purchase of resources and thus restrict production as they gather information about market conditions. The results are higher (than equilibrium) market prices in output markets due to restricted supplies and lower (than equilibrium) input prices due to restricted input demand. As the experience that producers gain from the market advances with the repetition and stationarity of parameters, the uncertainty diminishes (due to the accumulation of information about the market) and the randomness decreases (due to equilibration.) Output expands; output prices fall; and input prices rise. The results are an increasing input/output price ratio over time and falling profits. The conjecture that follows is simply that disequilibrium behavior is characterized by such a process.

Conjecture: Equilibration in the experiments follows the risk compensated input/output price adjustment process.

Support: All of the properties of the path, as described, are contained in the market data. Output prices converge toward the competitive equilibrium from above (Result 5). Input prices converge toward the competitive equilibrium (Results 6 and 7). Producer's

profits fall over time (Result 8) as the input/output price ratio increases.

The fact that input prices converge to the competitive equilibrium from below in environment 1 and converge from above in environment 2 is also consistent with the hypothesis. In environment 1 producers faced greater risks than in environment 2. In environment 2 producers were also consumers of factors so factors unused in production were valuable to them as consumption. In environment 1 producers had no such alternatives so the "down side" losses to producers was greater in environment 1 than in environment 2. The greater risk to producers in environment 1 would then be manifest in lower input prices.

Observation 3 is also consistent with the hypothesis that the disequilibrium is characterized by such a path. A tariff imposed on the imports of Z in country 1 (which has a comparative disadvantage in Z and thus consumes only imported in equilibrium) constitutes a major perturbation of the system. The natural tendency is for the price of Z in country 1 to be higher as a result of the tariffs. The risk compensated input/output price adjustment process exacerbates the increase of the price of Z in country 1 in the early period of an experiment. With the price of imported Z very high in country 1 due to the combined effects, some Z gets produced in country 1. On the other hand, in country 2, market demand for Z is reduced because there is reduced demand for exports. Thus, in country 2 the price of Z falls, making Z less profitable for country 2 producers relative to the production of Y whose market supply is reduced because some of the resources in country 1 are diverted to the production of Z. Some Y gets produced in country 2. Thus, along this disequilibrium path, country 1 (inefficiently) shifts production from a

full specialization in the production of Y to include the production of some Z. Country 2 shifts from a complete specialization in the production of Z to (inefficiently) include the production of some Y. The resulting inefficiencies are captured in the data from the experiments as summarized by Observation 3 and are shown in Figure 8. □

Of course, there is nothing theoretically new about profits being a return to producers for bearing market uncertainty. The new and difficult (theoretical) challenge stems from the fact that markets seem to have a natural, but inexplicable random component that is not captured by modern theory. The intuition that should support a theory seems clear but no formal statement of such a theory exists currently. The natural reaction of agents to the inherent randomness, would seem to be similar to any portfolio adjustment. The system adjustment to the individual hedging behavior appears natural enough. Since the path has such clearly distinguishable features it will be of interest to explore both other experiments as well as field data to see if system adjustments, along the risk compensated input/output price path, is found other places as well. And, it will be of interest to learn if the intuition captured by the explanation given above can be placed on solid theoretical footing.

6 Conclusion

The main result of the paper is that we observe experimentally for the first time, that the law of comparative advantage predicts patterns of trade and output. This result would

not have been completely unanticipated by trade theorists because it is so imbedded in modern economic models. However, the experiments, like naturally occurring economies, are complex, with mistakes, trading out of equilibrium, limitations on information, considerable uncertainty about the future and other prominent features that are not present in existing stylized models. Furthermore, the recent debates on U.S. competitiveness suggest that many people outside the economics research community do not believe that the law of comparative advantage works and are prepared to base policy on much different principles of system behavior. We find it remarkable that this fundamental principle operates with such strength and robustness even though the competitive model is statistically rejected. Were it not found operating, we would be forced to re-examine one of the deepest aspects of modern theories of the nature of trade and the existence of that very real possibility was an important consideration in the research design.

Generally, the qualitative predictions of the competitive model are upheld. Convergence processes are present so the competitive model receives better support in the later periods after equilibration takes place. This convergence takes place more quickly and strongly for quantities than for prices. The support of the competitive model extends itself to the qualitative impacts of a tariff. Support of this nature is very interesting since comparative statics models generally assume that the system is moving from one established equilibrium to another. In real markets, such as those studied here, disequilibria exist. There is little support for the autarky model in these experiments. International trade occurs in a natural way and must be considered in the application of models to any of the interacting countries.

Factor price equalization is a remarkable and unintuitive property. While this property is characteristic of only specialized environments it is important in helping us to see and understand that the principles of economics can lead to unintuitive and non-obvious results. That wages should equalize as a result of competition in output markets alone is such a proposition. Under the strong conditions in which theory suggests it will exist, we actually found it.

There was, although it was diminishing over time, a universal tendency for the factors of production to trade at prices below their marginal revenue product. The most plausible explanation is that the output prices adjusted upward and the input prices adjusted downward to compensate producers for the risk they undertook in producing the output. In later market periods, as output prices stabilized and the natural randomness that exists in markets tends to diminish, the producers' risk declined, input prices increased, output prices decreased, and producer profits fell. The process is well described by the term "risk compensated input/output price adjustment process." This somewhat surprising pattern is so plausible in retrospect that it leads to a speculation about whether it may be a general property of production economies observable in the field, especially those with extreme output price uncertainty, such as centrally planned systems in transition to market economies.

References

[1] Caves, R., J. Frenkel and R. Jones, *World Trade and Payments*, Fifth Edition, Scott Foresman/Little Brown, Glenview, Illinois, 1990.

[2] Chipman, J. S., A Survey of the Theory of International Trade: Part I, the Classical Theory, *Econometrica*, July, 1965, pp. 477-511.

[3] Devore, J., Probability and Statistics for Engineering and the Sciences, Brooks/Cole Publishing, Monterey, CA, 1982.

[4] Goodfellow, J. and C. Plott, An Experimental Examination of the Simultaneous Determination of Input Prices and Output Prices, *Southern Economic Journal*, Volume 56, Number 4, April 1990.

[5] Johnson, A., H. Lee, and C. Plott, Multiple Unit Double Auction User's Manual, California Institute of Technology Social Science Working Paper 676, 1988.

[6] Lian, P. and C. Plott, General Equilibrium, Macroeconomics and Money in a Laboratory Experimental Environment, mimeo, California Institute of Technology, 1991.

[7] Plott, C., Externalities and Corrective Policies in Experimental Markets, *Economic Journal* 93, March 1983, pp. 106-127.

[8] Smith, Vernon L. and Arlington Williams, "The Effects of Rent Asymmetries in Experimental Auction Markets," *Journal of Economic Behavior and Organization*, 3, March 1982, pp. 99-116.

APPENDIX A

INSTRUCTIONS

Several different instructions were used during the course of these experiments. Environments 1 and 2 differed because producers had redemption values for input goods in environment 2 but not in environment 1. There were also two input goods in environment 2 and only one input good in environment 1. The experiments with eight subjects had instructions that differed slightly from those with sixteen subjects. In the sixteen subject experiments a distinction was made between agent "type" (type 1 or type 2) while no such distinction was made between agents in the eight person experiments because the activities (producer and consumer) were combined. Then, there were the experiments in which an import tax existed. In reviewing the material that follows, the reader should appreciate that each of these several instructions was generated by only a few word changes (e.g., and/or vs or). A single paragraph added to the instructions explained the tariff in those experiments in which a tariff was operative.

The instructions hold two additional sources of potential ambiguity. The first is the labeling of markets. Three sets of labels exist throughout the series. For example, in the manuscript text of this paper the input from country 1 is labeled as L_1. However, in the instructions read to subjects, this input was called W and the trading activity of W took place in market 1 and is recorded that way in the data sets. Table A1 lists all of the relationships. The word "paper" refers to the manuscript in front of this appendix; the word "instructions" refers to what subjects saw; and the word "data/markets" indicates the index as presented on computer screens during the experiment and in the data sets.

TABLE A1: LABELS OF OUTPUT AND INPUT ACTIVITIES BY SOURCE: PAPER, INSTRUCTIONS, DATA SETS (MARKETS)

Environment 1			Environment 2		
Paper	Instructions	Data (Market)	Paper	Instructions	Data(Markets)
L_1	W	1	L_1	W_1	1
L_2	X	2	L_2	W_2	2
Y_1	Y_1	3	K_1	Y_1	3
Y_2	Y_2	4	K_2	Y_2	4
Z_1	Z_1	5	Y_1	X_1	5
Z_2	Z_2	6	Y_2	X_2	6
			Z_1	Z_1	7
			Z_2	Z_2	8

The second source of possible confusion is the assignments of subjects to agent types such as consumer/producer, etc. In sixteen person experiments there is no confusion. Subjects in country i control resources and/or consume and/or produce in country i. In the eight person sessions, the roles were different. The lack of subject numbers required functions of producer, consumer, and resource owner to be combined. Because of the small numbers an oligopoly problem presented itself. If the producers own resources in their own country then they could influence the activities of their competition by refusing to sell him/her the resources. In order to avoid this complicating factor firms were producers/consumers in one country but owned resources in the other country. Thus, producers/consumers in country i were resource owners in country j. Of course resource owners still could not transport the resources from one country to another.

Three sets of instructions follow. The first set is for the 8 person, environment 1, and the second is for the 16 person, environment 1. The third set is for the 16 person environment 2. The forms for the Redemption Value Sheets (for Consumption Decisions) were the same for all treatments as were the accounting forms. Blank examples of both are included at the end of the instructions. Of course, the redemption value sheets are filled in by the experimenter and the accounting sheets by the subject.

GENERAL INSTRUCTIONS

This is an experiment in the economics of market decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In your folder you have a sheet entitled Record Sheet for each period, and a sheet entitled Redemption Value Sheet for each period. You will also have a Production Schedule. These sheets will help you determine the value to you of any decisions that you might make. YOU ARE NOT TO REVEAL THE INFORMATION ON THESE SHEETS TO ANYONE. They are your own private information.

The currency used in this market is francs. All trading will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is ____ francs to 1 U.S. dollar. You will be paid at the end of the experiment.

There are four types of goods which will be traded in seperate markets: W, X, Y and Z. You may make profits in two ways, through consumption and through trading of the four goods.

CONSUMPTION

During each period you are free to purchase and sell as many units of W, X, Y and Z as you might want. Any units that you hold in your inventory at the end of the period are considered to be consumed by you. For the first unit of Y that you consume during a trading period you will receive the amount listed on your Redemption Value Sheet the column labelled Y Unit Value in the 1st row. If you consume a second unit you receive the amount listed in the column labelled Y Unit Value in the second row. The total amount that you receive from the consumption of both units is found in the column labelled Y Total Value in the second row. Notice that if you have unit values of zero in a space or a column that the corresponding units are worthless to you. The amount you receive from consumption

of Z is found in exactly the same way. The redemption value received from consumption of W and X is always zero.

TRADING PROFITS

Another source of profits is from buying and selling the four types of goods. Selling increases your cash on hand by the amount of the sale price. Buying reduces your cash on hand by the amount of the purchase. Thus you can either gain or lose money on the purchase and resale of units.

PRODUCTION

During each market period you are free to produce units of Y and Z from units of W and X. This is done with the Transformation Key (F4). When producing units of Y and/or Z from units of W or X use the table labelled Production Schedule. This table reflects the number of units of Y and/or Z that you can produce from given amounts of W or X for the whole period. You have already been instructed in how to read the production schedule but the following hypothetical example may provide further clarification.

Example: Suppose that you have 2 units of X and you have the Production Schedule shown on the next page. You can produce either:

a)8 units of Y

b)5 units of Y and 5 units of Z

c)8 units of Z

EARNINGS

Your profits each period are computed by taking the redemption values of the units of W, X, Y and Z that you consumed that period, adding the total sale price of the units of that you sold during the period and then subtracting the total of the prices you paid for the units that you bought during the period. The profits that you make exactly equal the change in your cash on hand from the beginning to the end of the period plus the redemption values of the units you consume.

Production Schedule (Each Period)

Identification Nc

Units of X (Input)	0	1	2	3	4	5	6	7	8	9	10	11	1
Unit Output (Y)	0	5	3	1	0	0	0	0	0	0	0	0	0
Total Output (Y)	0	5	8	9	9	9	9	9	9	9	9	9	9

Units of X (Input)	0	1	2	3	4	5	6	7	8	9	10	11	12
Unit Output (Z)	0	5	3	1	0	0	0	0	0	0	0	0	0
Total Output (Z)	0	5	8	9	9	9	9	9	9	9	9	9	9

At the end of the period enter the total number of units that you consume of W, X, Y and Z at the top of your Record Sheet. Then, fill out the rest of your record sheet as follows. In line 2, fill in your Cash on Hand at the beginning of the period. In line 1, fill in your cash on hand at the end of the period. In line 3 fill in line 1 minus line 2. In lines 4-7 fill in your earnings from the consumption of W, X, Y, and Z. In line 8 add the total of lines 4-7. In line 9 add the total of lines 3 and 8. This amount is equal to your profits for the period (in francs).

ENDOWMENTS

1) At the beginning of each period you will be given an endowment of either W or X. This endowment will appear in your inventory and will remain the same every period. You are free to sell any part of this endowment to anyone who might want to buy it.

2) At the beginning of the experiment you will receive 100000 francs cash on hand.

HOW THE SYSTEM WORKS

Participants are endowed with either W or X but would like to consume either Y or Z. They can sell W and X to increase their cash in order to buy Y and Z. They can also use W or X to produce Y and Z, which they can sell to increase their cash.

MARKET RESTRICTIONS

Some of you may not be able to trade in all markets. The experimenter will inform you of which markets are closed to you. Unless you are informed otherwise these markets will be closed to you for the entire experiment.

GENERAL INSTRUCTIONS

This is an experiment in the economics of market decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment, we are going to conduct a market in which you will be designated as one of two types of traders in a sequence of trading periods (either a type 1 or a type 2). Find your type at the top of the instructions. In your folder you have a sheet entitled Record Sheet. If you are a type 1, you will also have a Redemption Value Sheet. If you are a type 2 you will have a Production Schedule. These sheets will help you determine the value to you of any decisions that you might make. YOU ARE NOT TO REVEAL THE INFORMATION ON THESE SHEETS TO ANYONE. They are your own private information.

The currency used in this market is francs. All trading will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is ___ francs to 1 U.S. dollar. You will be paid at the end of the experiment.

There are four types of goods which can be traded in our market: W, X, Y and Z. You may make profits in two ways, through consumption and through trading of the four goods.

SPECIFIC INSTRUCTIONS TO TYPE 1 TRADERS

CONSUMPTION

During each period you are free to purchase and sell as many units of W, X, Y and Z as you might want. Any units that you hold in your inventory at the end of the period are considered to be consumed by you. For the first unit of Y that you consume during a trading period you will receive the amount listed on your Redemption Value Sheet the column labelled Y Unit Value in the 1st row. If you consume a second unit you receive the amount listed in the column labelled Y Unit Value in the second row. The total amount that you receive from the consumption of both units is found in the column labelled Y Total Value in the second row. Notice that if you have unit values of zero in a space or a column that the corresponding units are worthless to you. The amount you receive from consumption of Z is found in exactly the same way. The redemption value received from consumption of W and X is always zero.

SPECIFIC INSTRUCTIONS TO TYPE 2 TRADERS

PRODUCTION

During each market period type two traders are free to produce units of Y and Z from units of W and X. This is done with the Transformation Key (F4). When producing units of Y and/or Z from units of W and X use the table labelled Production Schedule. This table reflects the number of units of Y and/or Z that you can produce from given amounts of W and X for the whole period. You have already been instructed in how to read the production schedule but the following hypothetical example may provide further clarification.

Example: Suppose that you have 2 units of X and you have the Production Schedule shown on the next page. You can produce either:

a) 8 units of Y

b) 5 units of Y and 5 units of Z

c) 8 units of Z

INSTRUCTIONS TO BOTH TYPES

TRADING PROFITS

Another source of profits is from buying and selling the four types of goods. Selling increases your cash on hand by the amount of the sale price. Buying reduces your cash on hand by the amount of the purchase. Thus you can either gain or lose money on the purchase and resale of units.

Production Schedule (Each Period)

Identification Nc

Units of X (Input)	0	1	2	3	4	5	6	7	8	9	10	11	1
Unit Output (Y)	0	5	3	1	0	0	0	0	0	0	0	0	0
Total Output (Y)	0	5	8	9	9	9	9	9	9	9	9	9	9

Units of X (Input)	0	1	2	3	4	5	6	7	8	9	10	11	12
Unit Output (Z)	0	5	3	1	0	0	0	0	0	0	0	0	0
Total Output (Z)	0	5	8	9	9	9	9	9	9	9	9	9	9

EARNINGS

Your profits each period are computed by taking the redemption values of the units of W, X, Y and Z that you consumed that period, adding the total sale price of the units of that you sold during the period and then subtracting the total of the prices you paid for the units that you bought during the period. The profits that you make exactly equal the change in your cash on hand from the beginning to the end of the period plus the redemption values of the units you consume.

At the end of the period enter the total number of units that you consume of W, X, Y and Z at the top of your Record Sheet. Then, fill out the rest of your record sheet as follows. In line 2, fill in your Cash on Hand at the beginning of the period. In line 1, fill in your cash on hand at the end of the period. In line 3 fill in line 1 minus line 2. In lines 4-7 fill in your earnings from the consumption of W, X, Y, and Z. In line 8 add the total of lines 4-7. In line 9 add the total of lines 3 and 8. This amount is equal to your profits for the period (in francs).

ENDOWMENTS

1) At the beginning of each period you will be given an endowment of either W or X. This endowment will appear in your inventory and will remain the same every period. You are free to sell any part of this endowment to anyone who might want to buy it.

2) At the beginning of the experiment you will receive 100000 francs cash on hand.

HOW THE SYSTEM WORKS

Type 1 people are endowed with W or X but would like to consume Y and Z. They can sell W or X to type 2 people to increase their cash in order to buy Y and Z. Type 2 people are endowed with W or X but may purchase additional units from type 1 people. They can produce Y and Z from W or X and sell them to type 1 people to increase their cash.

MARKET RESTRICTIONS

Some of you may not be able to trade in all markets. You may not trade in markets

_____ . Unless you are informed otherwise these markets will be closed to you for the entire experiment.

You may be taxed for trading in market 6. The tax that you pay is ___ francs for each unit that you buy or sell in that market. Unless you are informed otherwise, the tax will remain the same for the entire experiment.

GENERAL INSTRUCTIONS

This is an experiment in the economics of market decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment, we are going to conduct a market in which you will be designated as one of two types of traders in a sequence of trading periods (either a type 1 or a type 2). Find your type at the top of the instructions. In your folder you have a sheet entitled Record Sheet and a sheet entitled Redemption Value Sheet. If you are a type 2 you will also have a Production Schedule. These sheets will help you determine the value to you of any decisions that you might make. YOU ARE NOT TO REVEAL THE INFORMATION ON THESE SHEETS TO ANYONE. They are your own private information.

The currency used in this market is francs. All trading will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is ___ francs to 1 U.S. dollar. You will be paid at the end of the experiment.

There are four types of goods which can be traded in our market: W, X, Y and Z. You may make profits in two ways, through consumption and through trading of the four goods.

CONSUMPTION

During each period you are free to purchase and sell many units of W, X, Y and Z as you might want. Any units that you hold at the end of the period are considered to be consumed by you. For the first unit of W that you consume during a trading period you will receive the amount listed on the left side attached Redemption Value Sheet in row (1) marked first unit redemption value, in the column labelled W. If you consume a second unit you receive the amount listed in row (4) marked 2nd unit redemption value in the column labelled W. The amount you receive from consumption of X, Y, and Z

is computed in exactly the same way. If you are a type 1 you always have zero redemption values for units of W and Y. If you are a type 2 you always have zero redemption values for units of X and Z.

TRADING PROFITS

Another source of profits is from buying and selling the four types of goods. Selling increases your cash on hand by the amount of the sale price. Buying reduces your cash on hand by the amount of the purchase. Thus you can either gain or lose money on the purchase and resale of units.

PRODUCTION

During each market period type 2 participants are free to produce units of X and Z from units of W and Y by transforming them. When producing units of X and/or Z from units of W and Y use the sheet labelled Production Schedule. This table reflects the number of units of X and/or Z you get from given amounts of W and Y for the whole period. Notice that you need W to produce X and you need Y to produce Z.

Example: Suppose that you have 1 unit of W and 2 units of Y and you have the Production Schedule shown on the next page. You can produce 1 unit of X, or 2 units of Z.

EARNINGS

Your profits each period are computed by taking the redemption values of the units of W, X, Y and Z that you consumed that period, adding the total sale price of the units of that you sold during the period and then subtracting the total price you paid for the units that you bought during the period. The profits that you make exactly equal the change in your cash on hand from the beginning to the end of the period plus the redemption values of the redemption values of the units you consume.

At the end of the period enter the total redemption value of all of the units that you consume of W, X, Y and Z at the bottom of your redemption value sheet. Then, fill out your record sheet as follows. In line 2, fill in your Cash on Hand at the beginning of the period. In line 1, fill in your cash on hand at the end of the period. In line 3 fill in line 1 minus line 2. In lines 4-7 fill in your earnings from

the consumption of W, X, Y, and Z. In line 8 add the total of lines 4-7. In line 9 add the total of lines 3 and 8. This amount is equal to your profits for the period (in francs).

ENDOWMENTS

1)At the beginning of each period type 1 participants will be given an endowment of W and Y. This endowment will remain the same every period. You are free to sell any part of this endowment to anyone who might want to buy it.

2)At the beginning of the experiment all participants will receive 10000 francs cash on hand.

HOW THE SYSTEM WORKS

Type 1 people are endowed with W and Y but would like to consume X and Z. They must sell W and Y to type 2 people who have the ability to produce X and Z from W and Y and then buy X and Z from them. Type 2 people would like to consume W and Y. They must buy them from type 1 people.

MARKET RESTRICTIONS

Some of you may not be able to trade in all markets. The experimenter will inform you of which markets are closed to you. These markets will be closed to you for the entire experiment.

Redemption Value Sheet

(For Consumption Decisions)

Unit	W unit value	W total value	X unit value	X total value	Y unit value	Y total value	Z unit value	Z total value
1								
2								
3								
4								
5								
6								
7								
8								

Record Sheet

Period # 1

W _____ X _____ Y _____ Z _____

(1) Cash on hand at end of period _____

(2) Cash on hand at beginning of period _____

(3) Net change in cash on hand (1) - (2) _____

Earnings from consumption

(4) W _____

(5) X _____

(6) Y _____

(7) Z _____

(8) Total earnings from consumption (4)+(5)+(6)+(7) _____

(9) TOTAL PROFITS FOR THE PERIOD _____

Appendix B

1.1 Significance Tests

The two following tables contain the result of numerous statistical tests conducted on the data supporting result 0. In both tables, in the columns labelled Competitive (Comp.) and Autarky (Aut.) are the levels of confidence with which we reject the predictions of the models for the variables listed the leftmost column. The averages for all of the variables in the tables for all experiments are given in tables B4 - B20.

TABLE B1: SIGNIFICANCE OF STATISTICAL TESTS OF THE TWO MODELS (NO TARIFFS)

	ENVIRONMENT 1		ENVIRONMENT 2	
	Comp.	Aut.	Comp.	Aut.
PRODUCTION				
Y	0.001	0.001	not.sig.	not.sig.
Z	not.sig.	0.001	not.sig.	not.sig.
EXPORTS				
Net Y (from 1 to 2)	0.001	0.001	0.001	0.001
Net Z (from 2 to 1)	0.01	0.001	0.001	0.001
PRICES				
L1	0.01	0.1	not.sig.	0.001
L2	0.001	0.01	not.sig.	0.001
K1	-	-	not.sig.	0.001
K2	-	-	not.sig.	0.001
Y1	0.001	0.001	0.001	0.001
Y2	-	-	0.01	0.001
Z1	-	-	0.05	0.001
Z2	0.001	0.001	0.001	0.001

In the second table, in the column labelled "Same as Notar" are the levels of confidence with which we reject that the observed values of a variable are equal under tariffs and no tariffs.

TABLE B2: SIGNIFICANCE OF STATISTICAL TESTS OF THE TWO MODELS (UNDER TARIFFS)

	ENVIRONMENT 1		
	Comp.	Aut.	Same as Notar
PRODUCTION			
Y	0.01	0.01	
Z	0.001	0.05	
EXPORTS			
Net Y (from 1 to 2)	0.001	0.001	
Net Z (from 2 to 1)	0.001	not.sig.	
PRICES			
L1	0.05	not.sig.	
L2	not.sig.	0.01	0.05
Y1	0.001	0.001	
Y2	-	0.1	
Z1	-	0.05	
Z2	0.001	0.01	0.05

1.2 Average Production and Exports

The following 9 tables summarize the data on the levels of production and exports observed in each of the experiments. The data are given for the entire experiment as well as for the early and late periods separately. Tables B3-B5 encompass the four experiments in the conditions of environment one with no tariffs. Each table reports averages for each experimental session; Table B3 pools the data from the entire experiment, and B4 and B5 report the data from periods 1-4 and periods 5 and greater respectively. In the table "net exports of "Y refers to the net transfer of Y from country 1 to country 2. "Net exports of Z" refers the net transfer of Z from country 2 to country 1.

TABLE B3: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 1: NO TARIFFS: ALL PERIODS

	Experiment Number				Comp.	Aut.
	03/05/91	04/01/91	04/11/91	04/13/91A		
Prod. of Y1	27.7	30	26.3	31.5	36	21
Prod. of Y2	1.45	3.1	1.6	1.1	0	5
Prod. of Z1	1.82	2	3.1	1.4	0	5
Prod. of Z2	28.9	25.8	28.9	29.8	32	22
Net Exp. of Y	9.6	10.9	9.9	16.1	18	0
Net Exp. of Z	12.2	10.6	7	11	16	0

TABLE B4: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 1: NO TARIFFS: PERIODS 1-4

	Experiment Number				Comp.	Aut.
	03/05/91	04/01/91	04/11/91	04/13/91A		
Prod. of Y1	22.5	27	20	29.3	36	21
Prod. of Y2	3.8	4.8	2.8	2	0	5
Prod. of Z1	3	3	4.5	2	0	5
Prod. of Z2	24	22.5	26.5	28	36	22
Net Exp. of Y	5	6.3	6.7	15	18	0
Net Exp. of Z	9.5	7.5	6	11	16	0

TABLE B5: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 1: NO TARIFFS: PERIODS 5 AND GREATER

	Experiment Number				Comp.	Aut.
	03/05/91	04/01/91	04/11/91	04/13/91A		
Prod. of Y1	31.5	32	29.6	33	36	21
Prod. of Y2	0.1	2	0.6	0.5	0	5
Prod. of Z1	1.1	1.3	2	1	0	5
Prod. of Z2	31.7	28	30.8	31	36	22
Net Exp. of Y	12.3	13.2	13.4	17	18	0
Net Exp. of Z	13.7	12.7	7.8	11	16	0

Tables B6-B8 summarize the observed levels of production and exports in the tariff condition. Table B6 contains data from entire experiments. tables B7 and B8 contain only data from early and late periods respectively.

TABLE B6: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 1: TARRIFS: ALL PERIODS

	Experiment Number			Comp.	Aut.
	03/20/91	04/10/91	04/13/91B		
Prod. of Y1	30.4	33	18.9	36	21
Prod. of Y2	2.2	5.1	7.1	0	5
Prod. of Z1	1.8	.9	5.4	0	5
Prod. of Z2	26.9	20.5	17.5	32	22
Net Exports of Y	11	10	4.4	18	0
Net Exports of Z	1.7	6.3	0.7	6	0

TABLE B7: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 1: TARRIFS: PERIODS 1-4

	Experiment Number			Comp.	Aut.
	03/20/91	04/10/91	04/13/91B		
Prod. of Y1	29.3	33.3	21	36	21
Prod. of Y2	2.8	7	7.5	0	5
Prod. of Z1	2.3	.8	5.0	0	5
Prod. of Z2	25.3	15	16.3	32	22
Net Exports of Y	5.5	7.0	4.2	18	0
Net Exports of Z	1.6	2	0.3	6	0

TABLE B8: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 1: TARRIFS: PERIODS 5 AND GREATER

	Experiment Number			Comp.	Aut.
	03/20/91	04/10/91	04/13/91B		
Prod. of Y1	31.7	32.9	17.5	36	21
Prod. of Y2	1.7	3.6	6.7	0	5
Prod. of Z1	1.5	1	5.7	0	5
Prod. of Z2	28	24.8	18.3	32	22
Net Exports of Y	14.1	12.4	4.6	18	0
Net Exports of Z	1.8	8.8	1	6	0

Tables B9-B11 contain information concerning production and exports in environment 2.

TABLE B9: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 2: ALL PERIODS

	Experiment Number			Comp.	Aut.
	11/28/90	11/30/90	1/18/91		
Prod. of Y1	9.1	9.6	11.4	12	10
Prod. of Y2	5.3	5.5	3.9	4	6
Prod. of Z1	6.3	5.6	5.6	4	6
Prod. of Z2	8.7	11.4	9.9	12	10
Net Exports of Y	1.8	1.9	2.8	4	0
Net Exports of Z	1.3	3.8	3.4	4	0

TABLE B10: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 2: PERIODS 1-4

	Experiment Number			Comp.	Aut.
	11/28/90	11/30/90	1/18/91		
Prod. of Y1	8	9.6	9	12	10
Prod. of Y2	6	6.8	5	4	6
Prod. of Z1	6	6.5	4.5	4	6
Prod. of Z2	8.8	11.8	9	12	10
Net Exports of Y	-0.3	1.8	2.2	4	0
Net Exports of Z	2.7	3.9	2.8	4	0

TABLE B11: PATTERNS OF PRODUCTION AND EXPORTS: ENVIRONMENT 2: PERIODS 5 AND GREATER

	Experiment Number			Comp.	Aut.
	11/28/90	11/30/90	1/18/91		
Prod. of Y1	10	9.6	13	12	10
Prod. of Y2	4.6	4.9	3.2	4	6
Prod. of Z1	6.6	5.1	6.3	4	6
Prod. of Z2	8.6	11	10.5	12	10
Net Exports of Y	3.6	2	3.3	4	0
Net Exports of Z	0.2	3.7	3.8	4	0

1.3 Average Market Prices

The next three nine tables summarize the average contract prices per period in each of the experimental sessions for all outputs and inputs. For each of the three experimental conditions, three tables are provided. In the first of the three tables the data is pooled for all periods of the experiments. In the second the data for the first four periods is given In the third, the data for periods five and greater is given.

TABLE B12: PRICES IN ENVIRONMENT 1: NO TARIFFS: ALL PERIODS

Commodity	Experiment Number				Comp.	Aut.
	03/05/91	04/01/91	04/11/91	04/13/91A		
L1	562	569	589	867	720	600
L2	522	522	552	615	760	520
Y1	301	313	340	474	240	200
Y2	-	350	628	391	-	520
Z1	433	523	581	571	-	600
Z2	440	479	391	566	380	260

TABLE B13: PRICES IN ENVIRONMENT 1: NO TARIFFS: PERIODS 1-4

Commodity	Experiment Number				Comp.	Aut.
	03/05/91	04/01/91	04/11/91	04/13/91A		
L1	521	527	547	816	720	600
L2	418	486	527	586	760	520
Y1	342	324	391	620	240	200
Y2	-	350	747	398	-	520
Z1	350	540	336	813	-	600
Z2	451	493	424	665	380	260

TABLE B14: PRICES IN ENVIRONMENT 1: NO TARIFFS: PERIODS 5 AND GREATER

Commodity	Experiment Number				Comp.	Aut.
	03/05/91	04/01/91	04/11/91	04/13/91A		
L1	585	603	617	908	720	600
L2	642	550	569	639	760	520
Y1	277	305	307	358	240	200
Y2	-	-	532	380	-	520
Z1	500	505	714	426	-	600
Z2	434	468	368	487	380	260

TABLE B15: PRICES IN ENVIRONMENT 1: UNDER TARIFFS: ALL PERIODS

Commodity	Experiment Number			Comp.	Aut.
	03/20/91	04/10/91	04/13/91B		
L1	612	694	529	720	600
L2	284	576	356	360	520
Y1	268	489	377	240	200
Y2	305	530	424	-	520
Z1	604	528	537	-	600
Z2	215	525	406	180	260

TABLE B16: PRICES IN ENVIRONMENT 1: UNDER TARIFFS: PERIODS 1-4

Commodity	Experiment Number			Comp.	Aut.
	03/20/91	04/10/91	04/13/91B		
L1	552	570	509	720	600
L2	241	294	342	360	520
Y1	294	586	373	240	200
Y2	350	496	426	-	520
Z1	-	451	476	-	600
Z2	339	580	468	180	260

TABLE B17: PRICES IN ENVIRONMENT 1: UNDER TARIFFS: PERIODS 5 AND GREATER

Commodity	Experiment Number			Comp.	Aut.
	03/20/91	04/10/91	04/13/91B		
L1	652	792	543	720	600
L2	314	801	365	360	520
Y1	251	412	380	240	200
Y2	260	558	423	-	520
Z1	604	586	573	-	600
Z2	199	481	365	180	260

TABLE B18: PRICES IN ENVIRONMENT 2: ALL PERIODS

Commodity	Experiment Number			Comp.	Aut.
	11/28/90	11/30/90	1/18/91		
Country 1					
L	292	211	280	200-250	150
K	282	228	234	200-250	300-350
Y	344	285	340	200-225	150
Z	346	287	296	200-225	300-350
Country 2					
L	271	268	278	200-250	300-350
K	259	256	217	200-250	150
Y	340	308	325	200-225	300-350
Z	324	306	306	200-225	150

TABLE B19: PRICES IN ENVIRONMENT 2: PERIODS 1-4

Commodity	Experiment Number			Comp.	Aut.
	11/28/90	11/30/90	1/18/91		
Country 1					
L	335	207	322	200-250	150
K	317	224	279	200-250	300-350
Y	432	356	417	200-225	150
Z	423	317	365	200-225	300-350
Country 2					
L	308	290	317	200-250	300-350
K	288	271	213	200-250	150
Y	407	356	382	200-225	300-350
Z	366	336	341	200-225	150

TABLE B20: PRICES IN ENVIRONMENT 2: PERIODS 5 AND GREATER

Commodity	Experiment Number			Comp.	Aut.
	11/28/90	11/30/90	1/18/91		
Country 1					
L	258	213	250	200-250	150
K	252	230	203	200-250	300-350
Y	274	261	286	200-225	150
Z	285	270	265	200-225	300-350
Country 2					
L	243	268	258	200-250	300-350
K	236	246	220	200-250	150
Y	289	281	290	200-225	300-350
Z	291	289	285	200-225	150

Appendix C

This appendix provides, for each of the two environments, a calculation of the competitive equilibrium of a continuous set of parameters of which the experimental parameters are an approximation.

1.1 Environment 1

Initial endowments of consumers are $L_1 = 12, L_2 = 16$. L_1 and L_2 are inelastically supplied.

The production technologies are: $\frac{\partial Y_1}{\partial L_1} = 3, \frac{\partial Z_1}{\partial L_1} = 1, \frac{\partial Y_2}{\partial L_2} = 1, \frac{\partial Z_1}{\partial L_1} = 2$

All producers have the utility function: u(m) = m, (m = cash).

Aggregate supply of Y, Z is: $Y_1 = L_1 * \frac{\partial Y_1}{\partial L_1} = 36, Z_2 = L_2 * \frac{\partial Z_2}{\partial L_2} = 32, Y_2 = 0, Z_1 = 0$.

Each consumer's utility function is:

$$600Y - 40Y^2 + 700Z - 40Z^2 + m = U(Y, Z, m)$$

Therefore, each consumer's marginal utilities are:

$$\frac{\partial U}{\partial Y} = 600 - 80Y$$

$$\frac{\partial U}{\partial Z} = 700 - 80Y$$

$$\frac{\partial U}{\partial m} = 1$$

Aggregate demand is:

$$AD(Y) = 600 - 10Y$$

$$AD(Z) = 700 - 10Z$$

$$AD(m) = 1$$

Aggregate demand in each country is:

$$AD(Y) = 600 - 20Y$$

$$AD(Z) = 700 - 20Z$$

$$AD(m) = 1$$

Equilibrium output and price are:

$$Y^* = 36, Z^* = 32$$

$$P_Y^*(Y^*) = 600 - 10(Y^*) = 240$$

$$P_Z^*(Z^*) = 700 - 10(Z^*) = 380$$

Input prices equal their marginal revenue product. Therefore:

$$P_{L_1}^* = P_Y^* \frac{\partial Y_1}{\partial L_1} = 240 * 3 = 720$$

$$P_{L_2}^* = P_Z^* \frac{\partial Z_2}{\partial L_2} = 380 * 2 = 760$$

1.2 Environment 2

Initial endowments of consumers are: $L_1 = K_2 = 20$ and $K_1 = L_2 = 12$

The production technologies are: $\frac{\partial Y_1}{\partial L_1} = 1, \frac{\partial Z_1}{\partial K_1} = 1, \frac{\partial Y_2}{\partial L_2} = 1, \frac{\partial Z_2}{\partial K_2} = 1$

Each producer in country i (i = 1,2) has utility function:

$$u(L_i, K_i, m) = 600L_i - 100L_i^2 + 600K_i - 100K_i^2 + m$$

Therefore, each producer's marginal utilities are:

$$\frac{\partial U}{\partial L_i} = 600 - 200L_i$$

$$\frac{\partial U}{\partial K_i} = 600 - 200K_i$$

$$\frac{\partial U}{\partial m} = 1$$

Therefore, aggregate demand for consumption of the inputs is:

$$AD(L_i) = 600 - 25L_i$$

$$AD(K_i) = 700 - 25K_i$$

$$AD(m) = 1$$

The supply curves of Y and Z for each of the four producers in country 1 are:

$$S(Y_1) = 0; Y_1 \leq 2, -400 + 200Y_1; Y_1 > 2$$

$$S(Z_1) = 200Z_1$$

The supply curves of Y and Z for each of the four producers in country 2 are:

$$S(Y_2) = 200Y_2$$

$$S(Z_2) = 0; Z_2 \leq 2, -400 + 200Z_2; Z_2 > 2$$

Aggregate supply in country 1 is:

$$AS(Y_1) = 0; Y_1 \leq 8, -400 + 50Y_1; Y_1 > 8$$

$$AS(Z_1) = 50Z_1$$

Aggregate supply in country 2 is:

$$AS(Y_2) = 50Y_2$$

$$AS(Z_2) = 0; Z_2 \leq 8, -400 + 50Z_2; Z_2 > 8$$

Aggregate world supply of Y and Z is:

$$AS(Y) = 0; Y \leq 8, -200 + 25Y; Y > 8$$

$$AS(Z) = 0; Z \leq 8, -200 + 25Z; Z > 8$$

Each consumer's utility function is:

$$600Y - 100Y^2 + 600Z - 100Z^2 + m = U(Y, Z, m)$$